Vol. XXI. *July, 1911.* *No. 2.*

BIOLOGICAL BULLETIN

I. TRUSTEES

AUGUST, 1910

EX OFFICIO

F. R. LILLIE, *Director,* University of Chicago.
GILMAN A. DREW, *Assistant Director,* University of Maine.
D. BLAKELY HOAR, *Treasurer,* 161 Devonshire Street, Boston, Mass.
THOS. H. MONTGOMERY, JR., *Clerk of the Corporation,* University of Pennsylvania.

TO SERVE UNTIL 1914

E. G. CONKLIN..... Princeton University.
ROSS G. HARRISON..... Yale University.
CAMILLUS G. KIDDER..... 27 William Street, New York City.
M. M. METCALF..... Oberlin College, Oberlin, Ohio.
WILLIAM PATTEN..... Dartmouth College, Hanover, New Hampshire.
CORNELIA M. CLAPP..... Mount Holyoke College, South Hadley, Mass.
JACOB REIGHARD..... University of Michigan, Ann Arbor, Mich.
W^m B. SCOTT..... Princeton University.

TO SERVE UNTIL 1913

NATHANIEL L. BRITTON..2965 Decatur Avenue, Bronx, New York City.
S. F. CLARKE..... Williams College, Williamstown, Mass.
CHARLES COOLIDGE..... Ames Building, Boston, Mass.
C. R. CRANE..... 2559 Michigan Boulevard, Chicago, Ill., President of the Board.
ALFRED G. MAYER..... Carnegie Institution, Washington, D. C.
T. H. MORGAN..... Columbia University.
ERWIN F. SMITH..... United States Department of Agriculture, Washington, D. C.
E. B. WILSON..... Columbia University.

TO SERVE UNTIL 1912

M. J. GREENMAN.....Wistar Institute of Anatomy and Biology, Philadelphia.
C. W. HARGITT.....Syracuse University.
C. A. HERTER[1].....University and Bellevue Medical School, New York City.
H. S. JENNINGS.....Johns Hopkins University.
GEORGE LEFEVRE.....University of Missouri.
D. P. PENHALLOW[1].....McGill University, Montreal, Canada.
A. P. MATHEWS.....University of Chicago.
G. H. PARKER.....Harvard University.

TO SERVE UNTIL 1911

H. C. BUMPUS.....University of Wisconsin, Madison, Wis.
W. A. LOCY.....Northwestern University, Evanston, Ill.
JACQUES LOEB.....Rockefeller Institute for Medical Research, New York City.
F. P. MALL.....Johns Hopkins University.
GEORGE T. MOORE.....Washington University, St. Louis.
L. L. NUNN.....Telluride, Colo.
JOHN C. PHILLIPS.....299 Berkeley Street, Boston, Mass.
C. O. WHITMAN[1].....University of Chicago.

[1] Deceased.

II. ACT OF INCORPORATION

No. 3170.

COMMONWEALTH OF MASSACHUSETTS

Be It Known, That whereas Alpheus Hyatt, William Sanford Stevens, William T. Sedgwick, Edward G. Gardiner, Susan Minns, Charles Sedgwick Minot, Samuel Wells, William G. Farlow, Anna D. Phillips and B. H. Van Vleck have associated themselves with the intention of forming a Corporation under the name of the Marine Biological Laboratory, for the purpose of establishing and maintaining a laboratory or station for scientific study and investigation, and a school for instruction in biology and natural history, and have complied with the provisions of the statutes of this Commonwealth in such case made and provided, as appears from the certificate of the President, Treasurer, and Trustees of said Corporation, duly approved by the Commissioner of Corporations, and recorded in this office;

Now, therefore, I, HENRY B. PIERCE, Secretary of the Commonwealth of Massachusetts, *do hereby certify* that said A. Hyatt, W. S. Stevens, W. T. Sedgwick, E. G. Gardiner, S. Minns, C. S. Minot, S. Wells, W. G. Farlow, A. D. Phillips, and B. H. Van Vleck, their associates and successors, are legally organized and established as, and are hereby made, an existing Corporation, under the name of the MARINE BIOLOGICAL LABORATORY, with the powers, rights, and privileges, and subject to the limitations, duties, and restrictions, which by law appertain thereto.

Witness my official signature hereunto subscribed, and the seal of the Commonwealth of Massachusetts hereunto affixed, this twentieth day of March, in the year of our Lord ONE THOUSAND, EIGHT HUNDRED AND EIGHTY-EIGHT.

HENRY B. PIERCE,
Secretary of the Commonwealth.

[SEAL.]

III. BY-LAWS OF THE CORPORATION OF THE MARINE BIOLOGICAL LABORATORY

I. The annual meeting of the members shall be held on the second Tuesday in August, at the Laboratory, in Woods Hole, Mass., at 12 o'clock noon, in each year, and at such meeting the members shall choose by ballot a Treasurer and a Clerk, who shall be, *ex officio*, members of the Board of Trustees, and Trustees as hereinafter provided. At the annual meeting to be held in 1897, not more than twenty-four Trustees shall be chosen, who shall be divided into four classes, to serve one, two, three, and four years, respectively, and thereafter not more than eight Trustees shall be chosen annually for the term of four years. These officers shall hold their respective offices until others are chosen and qualified in their stead. The Director and Assistant Director, who shall be chosen by the Trustees, shall also be Trustees, *ex officio*.

II. Special meetings of the members may be called by the Trustees, to be held in Boston or in Woods Hole at such time and place as may be designated.

III. The Clerk shall give notice of meetings of the members by publication in some daily newspaper published in Boston at least fifteen days before such meeting, and in case of a special meeting the notice shall state the purpose for which it is called.

IV. Twenty-five members shall constitute a quorum at any meeting.

V. The Trustees shall have the control and management of the affairs of the Corporation; they shall present a report of its condition at every annual meeting; they shall elect one of their number President and may choose such other officers and agents as they may think best; they may fix the compensation and define the duties of all the officers and agents; and may remove them, or any of them, except those chosen by the members, at any time; they may fill vacancies occurring in any manner in their own number or in any of the offices. They shall from time to time elect members to the Corporation upon such terms and conditions as they may think best.

VI. Meetings of the Trustees shall be called by the President, or by any two Trustees, and the Secretary shall give notice thereof by

written or printed notice sent to each Trustee by mail, postpaid. Seven Trustees shall constitute a quorum for the transaction of business. The Board of Trustees shall have power to choose an Executive Committee from their own number, and to delegate to such Committee such of their own powers as they may deem expedient.

VII. The President shall annually appoint two Trustees, who shall constitute a committee on finance, to examine from time to time the books and accounts of the Treasurer, and to audit his accounts at the close of the year. No investments of the funds of the Corporation shall be made by the Treasurer except approved by the finance committee in writing.

VIII. The consent of every Trustee shall be necessary to a dissolution of the Marine Biological Laboratory. In case of dissolution, the property shall be given to the Boston Society of Natural History, or some similar public institution, on such terms as may then be agreed upon.

IX. These By-Laws may be altered at any meeting of the Trustees, provided that the notice of such meeting shall state that an alteration of the By-Laws will be acted upon.

X. Any member in good standing may vote at any meeting, either in person or by proxy duly executed.

IV. TREASURER'S REPORT

For the Year Ending December 31, 1910

Income

Annual dues		$ 606.00
Donations (Charles R. Crane)		8,500.00
Miscellaneous:		
Interest on deposit	$ 38.89	
Rent of microscopes	14.00	
Bath house	52.40	
Div. on 35 shs. Woods Hole Yacht Club	350.00	
Mosquito survey	400.00	
Check not used	.82	856.11
Supply department		9,300.58
Mess (net)		551.97
Tuitions		4,150.00
		$23,964.66

Expenses

Administration	$ 900.00
Advertising	99.31
Biological Bulletin (net)	512.70
Boats and launch	1,502.77
Botany	10.05
Chemicals, chemist supplies, etc.	783.23
Fish trap	88.35
Instructors' salaries	3,180.00
Insurance	284.35
Interest	150.00
Labor	3,872.52
Mosquito survey	50.00

Periodicals and library supplies	789.60	
Postage	89.06	
Repairs	1,377.09	
Sundries	1,900.20	
Supply department	6,958.25	$22,547.48
Surplus		$ 1,417.18

ITEMIZED LIST OF SUNDRY EXPENSES FOR THE YEAR 1910

Announcements and expense mailing	$110.80
Ash cans	12.00
Care of cemetery lot	2.00
Carting ashes	33.95
Covering for ice	8.66
Dr. Drew's office expenses	225.78
Dr. Lillie's office expenses	104.00
Exchange on checks	31.70
Express	47.27
Freight and hauling	6.80
Gas machine expense	55.12
Howes' bill	36.64
Hubbard, J. G., services	60.00
Instruments, laboratory supplies	178.40
Laundry	21.36
Lecture expense	22.30
New York Calcium Light Company	7.38
Notary fees	3.00
Petty cash at Woods Hole	63.62
Premium on bond	7.50
Rent of microscopes	30.00
Rent of typewriter	9.00
Spring water	10.50
Stationery, office supplies	57.50
Steel hand cart	10.00
Sundry supplies	37.57
Teaming	2.20
Telephone	31.89
Travelling expenses	39.50

Treasurer's office, clerical services	520.00	
Trustees' dinner	16.00	
Veeder's expenses	24.76	
Water	65.00	
Wooden cases	8.00	
		$1,900.20

MARINE BIOLOGICAL LABORATORY INVESTMENTS

JANUARY 1, 1911

Reserve Fund

Amount of fund December 1, 1899	$4,553.14	
Received from life memberships	600.00	
Income to January 1, 1911	2,090.15	
Gain from sale of securities	372.20	
	7,615.49	
Paid for current expenses of Laboratory	6,000.00	$1,615.49
Reserve fund now consists of the following:		
$3000 Am. Tel. & Tel. Co. 4s cost	$2,921.25	
6 shs. Am. Smelting & Refining Co. Pfd. cost	732.00	
5 shs. General Electric Co. cost	756.25	
Cash	205.99	
	4,615.49	
The above stocks and bonds are held as collateral for loan of	3,000.00	$1,615.49

Library Fund

Amount of fund December 1, 1899	$ 866.15	
Income to January 1, 1911	701.47	
Gain from sale of securities	74.88	
Sale of rights	.81	$1,643.31
Library fund now consists of the following:		
3 shs. Am. Tel. & Tel. Co. cost	$ 383.25	
4/5 of $1000 Am. Tel. & Tel. Co. 4s cost	779.00	
1 sh. Am. Smelting & Refining Co. Pfd. cost	122.00	
2 shs. General Electric Co. cost	302.50	
Cash	56.56	$1,643.31

Lucretia Crocker Fund

Amount of fund December 1, 1899	$2,500.00	
Income after paying students' fees	522.41	
Sale of rights	1.90	$3,024.31
Lucretia Crocker Fund now consists of the following:		
18 shs. Vermont & Mass. R. R. Co. cost	$2,416.50	
1 sh. West End St. Ry. Co. cost	83.00	
1 sh. Am. Tel. & Tel. Co. cost	127.75	
1/5 of $1000 Am. Tel. & Tel. Co. 4s cost	194.75	
1 sh. General Electric Co. cost	151.25	
Cash	51.06	$3,024.31

V. THE DIRECTOR'S REPORT

To the Trustees of the Marine Biological Laboratory:

Gentlemen: I have the honor to submit herewith a report of the twenty-third session of the Marine Biological Laboratory for the year 1910, and some recommendations for future development.

We record with sorrow the loss by death during the year of three members of the board of trustees: Dr. C. A. Herter, Professor D. P. Penhallow and Professor C. O. Whitman. It is fitting that due expression of the sense of our loss should be given in the form of resolutions to be spread upon the minutes of the board and sent to the families of our lamented colleagues. The death of Professor Whitman was sudden and unexpected. He was taken with pneumonia on November 30 and died on December 6. Memorial services in his honor were held at the University of Chicago on December 8, and his body was laid in the laboratory lot in the Episcopal Cemetery at Woods Hole on December 10 in the presence of a small gathering of his former associates and friends, who alone were able to attend.

Professor Whitman's death may be said to mark the close of the first period of development of the Marine Biological Laboratory. As director for the first twenty-one years of the existence of the Laboratory, more than any other person he gave the Laboratory its status and its ideals. In a very fitting way, therefore, we may say that the Laboratory is a monument to his memory. But it is desirable and due that some permanent memorial should mark his last resting place near the institution that he loved so well, and it is recommended that a committee be appointed to take this matter in charge.

The staff of instruction in 1910 comprised 29 members, representing eighteen institutions. Acknowledgment should again be made to the members of the staff of investigation who rendered their services freely.

The attendance of workers at the laboratory comprised 62 investigators and 64 students—a total of 126 as compared with 66 investigators and 63 students, total, 129, in 1909, and 52 investigators, 48 students, total 100, in 1908. There was a gratifying increase in the number of subscribing institutions, from 19 in 1909 to 24 in 1910. One of the subscribing institutions of 1909 dropped out this year. The new subscribing institutions were Dartmouth College, Massachusetts Agricultural College, The Rockefeller Institute for Medical Research, The University of Illinois and the Washington University Alumni Association. The membership of the corporation was also somewhat increased. The receipts of the supply department increased from $8,549.55 in 1909, to $9,300.58, in 1910.

No definite progress was made in the plan for a permanent building during the year, except that steps have been taken to secure the possession of more land that is necessary for the protection of our present holdings. Success has been attained in this direction and I think we may say that we are distinctly nearer the realization of the permanent building, not only in point of time but in preparedness. This raises definitely two questions: first, as concerns the nature and use of the building, and second, concerning administration affairs of the laboratory.

As regards the building, I believe that the committee that was appointed December 30, 1909, was fully agreed that the new building should provide for the library and for a certain number of research rooms. This committee has not formally met and I do not present this as an official report from the committee. But on the assumption that provision would be made for research rooms on a more adequate scale and with better equipment than the present quarters, I think that we should begin to ascertain the attitude of certain universities and research institutions with reference to the maintenance of quarters for investigation to be available throughout the year. Such an inquiry may seem premature; but when we consider that the character of the building to be erected must depend to a certain extent upon the financial support of institutions for its maintenance, I think it will be admitted that we can not move too soon in the direction of receiving assurances.

The second question concerns administration. As matters now stand the burden of administering the affairs of the laboratory falls rather heavily on men who already have a full assignment of work in their own universities. There is no question but that the work of the laboratory could be made more effective in all respects if we had an administrative officer who devoted his entire time to the affairs of the laboratory; it is also questionable whether the laboratory can continuously retain the services of men under present conditions, when their work is given at the expense of effectiveness in their university work and their research. It is therefore recommended, that, as soon as may be, the office of assistant director be made a resident position for the entire year. Under such an arrangement all our relations should prosper better: with the investigators, with the students, and with institutions. The expense involved would probably be a diminishing amount owing to improvement in laboratory conditions generally.

As soon as plans are definitely under way for a permanent building, such an officer would be necessary to supervise the details decided on by the committee on the building, and to make investigations on behalf of the committee; and later when the laboratory was erected to receive investigators at other seasons of the year besides the summer. He should be furnished with assistance adequate to leave him sufficient time for research.

There are appended as parts of this report (1) a list of the staff, (2) lists of investigators and students in attendance, (3) a comparative tabular view of attendance, (4) the names of subscribing institutions, (5) the evening lectures, (6) a list of members of the corporation.

I. THE STAFF, 1910

F. R. LILLIE, DIRECTOR,

Professor of Embryology, University of Chicago.

GILMAN A. DREW, ASSISTANT DIRECTOR,

Professor of Biology, University of Maine.

ZOÖLOGY

I. INVESTIGATION

Zoölogy and Embryology

E. G. CONKLIN.....Professor of Zöology, Princeton University (Absent in 1910.)

GILMAN A. DREW.....Professor of Biology, University of Maine.

GEORGE LEFEVRE .....Professor of Zoölogy, University of Missouri. (Absent in 1910.)

FRANK R. LILLIE.....Professor of Embryology, University of Chicago.

THOS. H. MONTGOMERY, JR.Professor of Zoölogy, University of Pennsylvania.

T. H. MORGAN.....Professor of Experimental Zoölogy, Columbia University.

E. B. WILSON.....Professor of Zoölogy, Columbia University.

II. INSTRUCTION

WINTERTON C. CURTIS...Professor of Zoölogy, University of Missouri.

PAUL M. REA.....Professor of Biology, College of Charleston, and Director of the Charleston Museum.

EDWARD E. WILDMAN....Central High School, Philadelphia.

JOHN W. SCOTT.....Westport High School, Kansas City.

G. S. DODDS.....Fellow in Zoölogy, University of Pennsylvania.

H. J. SPENCER.....Assistant in Zoölogy, Columbia University.

EMBRYOLOGY

I. INVESTIGATION. (See Zoölogy)

II. INSTRUCTION

GILMAN A. DREW.....Professor of Biology, University of Maine.
LORANDE L. WOODRUFF...Assistant Professor of Biology, Yale University.
WILLIAM E. KELLICOTT..Professor of Biology, Goucher College.
ROBERT A. BUDINGTON...Associate Professor of Zoölogy, Oberlin College.

PHYSIOLOGY

I. INVESTIGATION

ALBERT P. MATHEWS....Professor of Physiological Chemistry, University of Chicago.
E. P. LYON.....Professor of Physiology, University of St. Louis.
R. S. LILLIE.....Instructor in Comparative Physiology, University of Pennsylvania.

II. INSTRUCTION

H. H. NEWMAN.....Professor of Zoölogy, University of Texas.
FRANK P. KNOWLTON....Professor of Physiology, Syracuse University.
F. H. PIKE.....Instructor in Physiology, University of Chicago.

PHILOSOPHICAL ASPECTS OF BIOLOGY AND ALLIED SCIENCES

LECTURES

EDWARD G. SPAULDING...Assistant Professor of Philosophy, Princeton University.

BOTANY

GEORGE T. MOORE.....Professor of Plant Physiology and Applied Botany, Washington University.
GEORGE R. LYMAN.....Assistant Professor of Botany, Dartmouth College.

B. M. DUGGAR.....Professor of Plant Physiology, Cornell University.
I. F. LEWIS.....Professor of Biology, Randolph-Macon College.
LEWIS KNUDSON .....Instructor in Plant Physiology, Cornell University.

LIBRARY

H. McE. KNOWER.....University of Cincinnati, Librarian.

CHEMICAL SUPPLIES

OLIVER S. STRONG.....College of Physicians and Surgeons, Chemist.

G. M. GRAY.....Curator of Supply Department.
THOMAS M. DOUTHART..Collector in Zoölogy.
ARTHUR W. TAYLOR.....Collector in Botany, Salem High School, Salem, Mass.
JOHN VEEDER .....Cockswain.

2. INVESTIGATORS

1910

OCCUPYING ROOMS

1. ZOÖLOGY

ADDISON, W. H. F., University of Pennsylvania.
BECKWITH, CORA J., Instructor in Biology, Vassar College.
BROWNE, ETHEL N., Instructor, Bennett School, Millbrook, New York.
BUDINGTON, ROBERT A., Associate Professor of Zoölogy, Oberlin College.
CARY, L. R., Princeton University, Princeton, N. J.
CLARK, ELIOT R., Associate in Anatomy, Johns Hopkins University.
CURTIS, W. C., Professor of Zoölogy, University of Missouri.
DODDS, GIDEON S., Professor of Biology, St. Louis University Medical School, St. Louis, Mo.
DREW, GILMAN A., Professor of Biology, University of Maine.
HARRISON, ROSS G., Bronson Professor of Comparative Anatomy, Yale University.
HARVEY, E. NEWTON, Columbia University, New York City.
JARVIS, MAY M., Tutor in Zoölogy, University of Texas.
KELLICOTT, WILLIAM E., Professor of Biology, Goucher College.
KNOWER, HENRY MCE., Professor of Anatomy, University of Cincinnati.
LILLIE, FRANK R., Professor of Embryology, University of Chicago.
LOEB, LEO, Assistant Professor of Experimental Pathology, University of Pennsylvania.
MCINDOO, NORMAN E., Fellow in Biology, University of Pennsylvania.
MONTGOMERY, T. H. JR., Professor of Zoölogy, University of Pennsylvania.
MORGAN, T. H., Professor of Experimental Zoölogy, Columbia University.
MURBACH, LOUIS, Central High School, Detroit, Michigan.
PATTERSON, J. THOMAS, Instructor in Zoölogy, University of Texas.
QUACKENBUSH, L. S., Columbia University.
REA, PAUL M., Professor of Biology, College of Charleston.
SCOTT, JOHN W., Westport High School, Kansas City, Mo.
SPENCER, HENRY J., Assistant in Zoölogy, Columbia University.
SPAULDING, EDWARD G., Assistant Professor of Philosophy, Princeton University.
STRONG, O. S., Instructor in Anatomy, College of Physicians and Surgeons, New York City.
WATKINSON, GRACE B., Columbia University.
WERBER, ERNEST I., Assistant in Anatomy, Johns Hopkins University.
WELLS, H. G., Associate Professor of Pathology, University of Chicago.
WILDMAN, EDWARD E., Central High School, Philadelphia, Pa.

WILSON, E. B., Professor of Zoölogy, Columbia University.
WOODRUFF, L. L., Assistant Professor of Biology, Yale University.

2. PHYSIOLOGY

DONALDSON, H. H., Professor of Neurology, Wistar Institute.
HIRSCHFELDER, ARTHUR D., Associate in Medicine, Johns Hopkins Medical School.
KNOWLTON, FRANK P., Professor of Physiology, Syracuse University, College of Medicine.
KING, W. O. REDMAN, Rockefeller Institute for Medical Research, New York City.
LOEB, JACQUES, Rockefeller Institute for Medical Research, New York City.
LILLIE, R. S., Instructor in Physiological Zoölogy, University of Pennsylvania.
MATHEWS, A. P., Professor of Physiological Chemistry, University of Chicago.
NEWMAN, H. H., Professor of Zoölogy, University of Texas.
PIKE, FRANK H., Instructor in Physiology, University of Chicago.
ROGERS, CHARLES G., Associate Professor of Physiology, Syracuse University.
WASTENEYS, HARDOLPH, Rockefeller Institute for Medical Research, New York City.

3. BOTANY

BESSEY, ERNEST A., Professor of Botany, Michigan Agricultural College.
DUGGAR, BENJAMIN M., Professor of Plant Physiology, Cornell University.
KNUDSON, LEWIS, Instructor in Plant Physiology, Cornell University.
LEWIS, IVEY FOREMAN, Professor of Biology, Randolph-Macon College.
LYMAN, GEORGE R., Assistant Professor of Botany, Dartmouth College.
MOORE, GEORGE T., Professor of Plant Physiology and Applied Botany, Washington University, St. Louis, Mo.
THOMAS, MASON B., Professor of Botany, Wabash College.
OSTERHOUT, W. J. V., Assistant Professor of Botany, Harvard University.
SMITH, ERWIN F., Pathologist in charge Laboratory of Plant Pathology, U. S. Department of Agriculture, Washington, D. C.

OCCUPYING TABLES

1. ZOÖLOGY

ALLYN, HARRIET, University of Chicago.
DAVIS, SARAH ELLEN, Student, Columbia University.
LINTON, ELEANOR A., Washington, Pa.
KELLEY, FRANK, J., University of Pennsylvania.
WILSON, HERRICK E., Assistant in Geology, Oberlin College.
SPOONER, GEORGIANA B., Palo Alto, Cal.

2. PHYSIOLOGY

DONALDSON, JOHN CALVERT, 3310 Race Street, Philadelphia, Pa.
TASHIRO, SHIRO, Fellow, University of Chicago.

3. BOTANY

TAYLOR, ARTHUR W., Warren, Mass.

STUDENTS

1910

INVERTEBRATE ZOÖLOGY

Baker, Rita G., 72 Huntington Avenue, Boston, Mass.
Bell, Mary M., Oberlin College, Oberlin, Ohio.
Bodwell, Helen E., 137 Main Street, Andover, Mass.
Cashman, Marie E., Syracuse University, Syracuse, New York.
Coar, Herbert G., Dartmouth College, Hanover, N. H.
Eddowes, Florence E., Goucher College, Baltimore, Md.
Estabrook, A. H., Johns Hopkins University.
Fenner, Hattie, University of Kansas, Lawrence, Kansas.
Field, Leanor A., Mount Holyoke College, South Hadley, Mass.
Gavin, Helen, 28 West 97th Street, New York City.
Krantz, Hazel I., Syracuse University, Syracuse, N. Y.
Lee, Horace N., University of Maine, Orono, Maine.
McLaine, Leonard S., Massachusetts Agricultural College.
Martin, Bertha E., Mount Holyoke College, South Hadley, Mass.
Martin, Susie E., Mount Holyoke College, South Hadley, Mass.
Mase, Yae Kemesaki, Aichiken, Japan.
Mook, Charles C., Columbia University, New York City.
Moon, Evangeline A., 436 Manhattan Avenue, New York City.
Morriss, May J., 485 Central Park West, New York City.
Osgood, Marian S., Mount Holyoke College, South Hadley, Mass.
Paige, Beryl H., Mount Holyoke College.
Patten, Hazel, Goucher College, Baltimore, Md.
Pearson, Leonard S., Academy of Natural Sciences, Philadelphia.
Sevin, Gertrude K., Syracuse University.
Sink, Emory W., University of Michigan, Ann Arbor, Mich.
Topp, Emily, 428 West 20th Street, New York City.
Wilkinson, George N., Bucknell University, Williamsport, Pa.
Williams, Annie E., Cochituate, Mass.
Wiswell, Amy P., East Machias, Maine.
Wright, Coila B., Sheridan, New York.
Zabriskie, Helen M., Vassar College, Poughkeepsie, N. Y.

EMBRYOLOGY

Abbott, Margaret B., 413 West Front Street, Plainfield, N. J.
Appleton, Joseph L., State College, Pa.
Ennis, Agnes A., Barnard College, Columbia University.
Just, Ernest E., Howard University, Washington, D. C.
Kuntz, Albert, State University of Iowa.

LEAVITT, GEORGE C., University of Maine, Orono, Maine.
MELLEN, IDA M., 530 Carleton Avenue, Brooklyn, New York.
PRENTISS, HENRIETTA, Normal College, New York City.
REDELINGS, LESLIE R., Northwestern University, Evanston, Ill.
SMITH, ISABEL S., Illinois College, Jacksonville, Ill.
ULLMAN, HENRY J., Rush Medical College, Chicago, Ill.

PHYSIOLOGY

DAVIS, NATHAN SMITH III, 8 E. Huron Street, Chicago, Illinois.
MARKS, HENRY S., University of Rochester, Rochester, N. Y.
STARK, MARY B., St. Olaf College.
STEPHENSON, J. C., University of Chicago, Chicago, Ill.
WHITENTON, ROBERT O., University of Chicago, Chicago, Ill.

BOTANY

1. Plant Structures and Responses

CHANDLER, JEAN FORREST, 4651 North Lincoln Street, Chicago, Ill.
CLEMENT, FRANK H. P., Tilton, N. H.
WELLS, COLLIN, Dartmouth College, Hanover, N. H.
JENNISON, HARRY M., Massachusetts Agricultural College.

2. Morphology and Taxonomy of the Algæ

BRUGGER, HELEN F., Mount Holyoke College, South Hadley, Mass.
COLLEY, REGINALD H., Dartmouth College, Hanover, N. H.
CURTIS, OTIS F., Oberlin College, Oberlin, Ohio.
DAWSON, AVA B., 97 Mountfort Street, Boston, Mass.
HILL, ALBERT F., Dartmouth College, Hanover, N. H.
HOBBS, ETHELYN, Wellesley College, Wellesley, Mass.
IRWIN, JAMES M., Dartmouth College, Hanover, N. H.
LEIGHTON, HELEN, 68 Park Avenue, Canandaigua, New York.
ROBERTS, EDITH A., Mount Holyoke College, South Hadley, Mass.
RUTHERFORD, ELIZABETH E., 624 Fullerton Parkway, Chicago, Ill.
SPARGO, MILDRED W., 5050 Maple Avenue, St. Louis, Mo.
WALLBURG, AMY B., 54 Dale Street, Roxbury, Mass.
WILLISTON, RUTH, 297 Crown Street, New Haven, Conn.

3. TABULAR VIEW OF ATTENDANCE

	1907	1908	1909	1910
INVESTIGATORS—Total	60	52	66	62
Occupying Rooms				
Zoölogy	32	32	39	33
Physiology	8	6	7	9
Botany	10	8	4	9
Occupying Tables				
Zoölogy	9	6	14	5
Physiology	1		2	2
Botany				1
STUDENTS—Total	47	48	63	64
Zoölogy	34	19	36	31
Embryology		15	12	10
Physiology	4	3	9	5
Botany	9	11	6	17
UNIVERSITIES AND COLLEGES REPRESENTED	47	51	47	49
By Investigators	26	25	27	26
By Students	21	26	20	24

4. SUBSCRIBING INSTITUTIONS, 1910

Academy of Natural Sciences, Philadelphia.
Columbia University.
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5. EVENING LECTURES, 1910

JACQUES LOEB ..... "How Does the Spermatozoön Cause the Development of the Egg?"... July 1.

C. BOWYER VAUX..... "How to Prepare a Paper for Publication" ..... July 5.

JOHN B. SMITH..... "Mosquitoes and Mosquito Campaigns" ..... July 8.

H. H. DONALDSON.... "The Percentage of Water in the Central Nervous System of Vertebrates" ..... July 12.

W. J. V. OSTERHOUT.. "Some Aspects of the Action of Mineral Salts upon Plants"..... July 15.

E. B. WILSON..... "Heredity and the Chromosomes".. July 19.

B. M. DUGGAR..... "The Relation of Plants to Toxic Agents, with Special Reference to the Modification of Toxicity by Chemical and Physical Agents".. July 26.

R. M. YERKES..... "The Relation of Psychology to Biology" ..... July 29.

J. T. PATTERSON..... "The Questions of Specific Polyembryony and the Determination of Sex in the Armadillo"..... Aug. 4.

RALPH B. PERRY..... "When is a Thing Explained for the Purpose of Science"..... Aug 5.

RAYMOND PEARL ..... "The Inheritance of Fecundity in the Domestic Fowl" ..... Aug. 9.

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THE SEX RATIO IN HYBRID RATS.

HELEN DEAN KING.

THE WISTAR INSTITUTE OF ANATOMY AND BIOLOGY.

It has frequently been stated that the sex ratio in mammals can be altered by hybridizing, although there are but few series of observations that give support to such a view. Buffon (1709–1788) seems to have been one of the first to note the apparent excess of males among hybrid offspring; but as his records comprise only a comparatively small number of cases they cannot be considered to afford conclusive evidence that hybridizing changes the normal proportion of the sexes.

In recent times little attention has been paid to the question of the sex ratio in hybrid offspring. Davenport ('06) ascertained the sex of 377 out of a total of 950 hybrid fowls obtained in an extensive series of investigations on inheritance in poultry, and found 204 males and 173 females. Taking the sex ratio for any given lot of individuals as the number of males to each 100 females, it is found that among these hybrids the sexes exist in the ratio of 117.91 males to 100 females. This sex ratio seems to indicate that there is a pronounced excess of males among hybrid fowls, yet Davenport states that the proportion of the sexes in hybrids is normal, and that "the exceptions to the law of equality of sexes in hybrid offspring are individual and not of general significance." Davenport attributes the excess of males among his 377 hybrid fowls to a difference in the death rate of the two sexes, yet he gives no figures to show that among young poultry more females die than do males. Human statistics, as well as the records I have been collecting for the albino rat, indicate that mortality is greater among young males than among young females. Davenport's conclusion does not appear to apply to hybrid birds in general, as Guyer ('03, '09) found a great excess of males among hybrid pigeons, and the data which he has collected regarding the sex of other hybrid birds show a very much greater number of males than of females in practically every case.

In order to study the color combinations in hybrid mice von Guaita ('98, '00) crossed albino mice with Japanese waltzing mice and inbred their descendants through six generations. In his various tables von Guaita gives the sex of the great majority of the hybrid offspring obtained in each generation, yet he makes no comment whatever on the relative proportion of the sexes in these individuals. For the purpose of comparing the sex ratio in hybrid mice with that in hybrid rats, von Guaita's sex records have been collected and the sex ratios calculated for the individuals in each generation. The data thus obtained are shown in the following table.

TABLE I.

SEX DATA FOR HYBRID MICE (VON GUAITA).

Generation.	No. Hybrids.	Sex Unknown.	Males.	Females.	No. Males to 100 Females.
F_1	31	3	16	12	133.33
F_2	45	0	21	24	87.50
F_3	77	0	39	38	102.63
F_4	134	21	60	53	113.20
F_5	95	9	48	38	126.31
F_6	25	18	5	2	
	407	51	189	167	113.17

According to these records von Guaita obtained a total of 407 hybrid mice; but he gives the sex of only 356 individuals, of which 189 were males and 167 were females. In this lot of hybrids, therefore, there are 113.17 males to 100 females. This sex ratio is undoubtedly higher than that which is normal for either of the two species with which the experiments began. Schultze ('03) found a nearly equal proportion of the sexes in over 1,000 albino mice that had been bred under different environmental conditions; a similar relation between the sexes existed in the 135 waltzing mice bred by Yerkes ('07).

Raymond and Maud D. Pearl ('08) have tabulated over two hundred thousand records of legitimate births occurring in the city of Buénos Ayres during the years 1896–1905 inclusive, in order to ascertain whether there is a tendency towards an excessive production of offspring of one sex in cross as compared with pure matings. Their tables show that in pure matings, either among Argentine, Italian or Spanish stock, the number of males

to each 100 females ranges from 100.77 to 105.55 in various cases. Among these races, therefore, the same relation of the sexes exist as is normally found when any large number of human births are examined. When the parents were of different racial stock there is a marked increase in the relative number of males; the sex ratio showing from 105.72 to 106.74 males for each 100 females. The general conclusion reached by these investigators is that "there is a definite tendency towards an excessive production of male offspring in cross as compared with pure matings in the data considered. Further, it appears that this tendency is uniformly exhibited in all the matings."

The records given above comprise all the sex data for considerable numbers of hybrid offspring that I have been able to find. All of these records are in complete accord, since in each case there is an excess of males that is much greater than that which is probably normal for the parent stock.

For several years past Dr. S. Hatai, of the Wistar Institute, has been crossing the wild Norway rat (*Mus norvegicus*) with the albino rat (*Mus norvegicus albinus*) and breeding their descendants, in order to obtain material for a study of the central nervous system in hybrid rats. The records for the many hybrid offspring that have been examined include the sex data, and Dr. Hatai has generously offered me the use of these records for the study of the sex ratios that is given in the present paper. As far as I am aware, there are no published statistics regarding the proportion of the sexes among hybrid rats, although three investigators, von Fischer ('74), Crampe ('84) and Bos ('94), have carried on extensive hybridizing and inbreeding experiments with these animals.

Cuénot ('99) examined 30 litters of young albino rats containing a total of 255 individuals, and found among them a sex ratio of 105.6 males to 100 females. Records which I have made of the sex of 452 young albino rats belonging to 80 litters give a sex ratio of 107.33 males to 100 females. The sex ratio in the albino rat, therefore, agrees with that for man and various other mammals, since the number of the males is slightly greater than that of the females.

No statistics have as yet been collected regarding the normal

proportion of the sexes among wild Norway rats. Judging from the sex ratio found in general among the mammals, it is very probable that there is approximately an equality of the sexes in the wild Norway rat as in the albino rat. In the total of 607 albino rats examined by Cuénot and by myself there was found a sex ratio of 106.46 males to 100 females. This sex ratio is considered, throughout this paper, to express the probable normal relation between the sexes in the wild rat as well as in the albino rat.

Four series of experiments were made in which albino rats were crossed with wild Norway rats. Records are available for a total of 163 individuals belonging to the F_1 generation, of which 89 were males and 74 were females. Among these hybrids, therefore, there is a sex ratio of 120.26 males to 100 females. Although this sex ratio is much higher than that which is probably normal for either of the parent species, it is not as high as that found in von Guaita's first generation of hybrid mice where the sexes existed in the ratio of 133.33 males to 100 females (Table I.).

All of the hybrid rats belonging to the F_1 generation for which records were made were at least five months old when they were killed and examined; the few individuals that died before reaching maturity were not included in the records. It cannot be determined with any degree of certainty, therefore, to what proportion of the entire number of offspring belonging to the F_1 generation the above sex ratio applies. Very few of the young rats died, as far as is known, and there is no reason to suppose that the mortality was greater among the young females than among the young males. It seems probable, therefore, that the sex ratio in the 163 individuals for which data are available is fairly representative for the entire number of offspring produced in the course of the various experiments to which they belonged.

Two of the four series of experiments mentioned above were extended by mating various individuals belonging to the first generation of hybrids. In pairing these animals no attention was paid to their blood relationship, and undoubtedly nearly related individuals were mated in many cases.

In one series of experiments only a very small number of individuals belonging to the second generation of hybrids died

before reaching maturity, and the 114 rats for which records are at hand form a very great majority of all of the offspring produced. Of these individuals 61 were males and 53 were females; this gives a sex ratio of 115.09 males to 100 females.

In the other series of experiments the majority of the individuals belonging to the F_2 generation died while immature, and records were made for only 27 individuals. Since twice as many females as males reached maturity, it is evident that in this instance either the mortality was much greater among the young males than among the young females or that there was a very unequal distribution of the sexes in the newborn rats.

Individuals from only one lot of hybrids belonging to the second generation were mated. The animals were paired according to color, their possible blood relationship being entirely disregarded. Dr. Hatai found, as have other investigators who have bred hybrid rodents, that there is increasing infertility among individuals belonging to succeeding generations of hybrids. The total number of hybrid offspring belonging to the F_3 generation was relatively small: many of the rats were stunted in their development, and the majority of them died before reaching maturity. Since records are available for only 23 of these individuals the sex ratio among them can give no idea of the probable ratio in a large number of hybrids belonging to the third generation.

Since in mating individuals belonging to the first and to the second generation of hybrids no attention was paid to their blood relationship, it is very probable that in some cases closely related individuals were paired. There is the possibility, therefore, that inbreeding might have had some influence on the sex of the descendants. According to Düsing ('84), a noticeable increase in the number of male offspring is produced by inbreeding, in man as well as in various mammals. Inbreeding could have had little, if any, influence on the sex ratios in these various lots of hybrid rats. The sex ratio found among the 114 hybrids of the F_2 generation which comprise practically all of the offspring produced in the series of experiments to which they belonged, is somewhat less than that found among the offspring produced by crossing pure stock (Table II.). The data for

the other individuals belonging to the F_2 generation, as well as those for the hybrids of the F_3 generation, show an excess of females. These latter records cannot be considered to furnish evidence against Düsing's theory, since they include such a very small number of individuals. There seem to be no records, except those given by Düsing, that show that inbreeding alone produces a relatively greater number of male than of female offspring. Schultze was unable to detect any change in the sex ratio of albino mice that had been inbred for four generations, and I have found no unusual excess of males among some 500 individuals belonging to five generations of inbred albino rats.

Records are available for 121 other hybrid rats, most of which were the offspring of reciprocal crosses. These individuals all belonged to the F_2 or to the F_3 generation of hybrids; and among them were 72 males and 49 females. These hybrids were selected, because of their size and condition, from a considerable number of individuals for which no records were made. There was, therefore, undoubtedly an unconscious selection of males in choosing the rats to be examined, since the adult male rat is considerably larger and heavier than the female. The data for these various lots of selected individuals have been combined in one group, since they are of value only because they show the sex of a considerable number of hybrids.

The following table gives a summary of the sex records for all of the hybrid rats recorded.

TABLE II.

SEX DATA FOR HYBRID RATS.

Generation.	No. Hybrids.	Males.	Females.	No. Males to 100 Females.
F_1	163	89	74	120.26
F_2	114	61	53	115.09
F_2	27	9	18	50.00
F_2 and F_3	121	72	49	146.93
	425	231	194	119.07

In the total of 425 hybrid rats for which records were made, 231 were males and 194 were females. Among these individuals, therefore, there is found a sex ratio which is considerably higher than that which is probably normal for either the albino or the wild Norway rat, since there are 119.09 males to 100 females.

If from the above table we omit the records for the 27 individuals belonging to the F_2 generation of hybrids which formed only a very small percentage of the total number of offspring produced in the experiment to which they belonged and also the records for the selected individuals belonging to the F_2 and to the F_3 generation, there remain the data for 277 individuals which comprise the very great majority of the hybrid offspring obtained in several series of experiments. It would seem as if the sex ratio in these individuals might justly be taken to represent the probable sex ratio in any large lot of hybrid rats. Of these individuals 150 were males and 127 were females; this gives a sex ratio of 118.11 males to 100 females. This sex ratio is but very little lower than that found in the total number of hybrids for which records are at hand, and it is not very much higher than that in the 356 hybrid mice bred by von Guaita (Table I.).

The excess of males among these hybrid rats is seemingly beyond the limits of normal variation in the proportion of the sexes in the pure stock, and it is too uniform in the various series of experiments to be attributed to chance. It appears, therefore, that hybridizing alters the sex ratio by producing a marked increase in the relative proportion of males. This conclusion is in essential agreement with that reached by Buffon, by R. and M. Pearl and by Guyer.

Guyer ('09) has offered an explanation for the excess of males among hybrid offspring which accords with the theory, advocated by a number of investigators, that sex is determined in the ovary chiefly by nutritive conditions. Guyer suggests that in the zygote produced by cross fertilization there would probably be "more or less default in the metabolic processes because of the incompatibilities which must necessarily exist between two germplasms so dissimilar." An interference with the metabolic processes would naturally retard the constructive phases of metabolism in the fertilized ovum, and therefore tend to the production of relatively more males, since the theory assumes that females are produced only when the conditions are most favorable for constructive metabolism.

To explain the sex ratio in hybrids according to the current

hypothesis that the male is the sex-determining factor seems to necessitate the further assumption that fertilization is selective when individuals belonging to different races are crossed, the egg offering greater resistance to the entrance of a spermatozoan that is female-producing than to one that is male-producing. There is little evidence, as yet, that fertilization is ever selective. The probability of its occurrence as a normal phenomenon has recently been advocated by Heape ('09), although Wilson ('10) considers it "so improbable as almost to invalidate any interpretation into which it enters."

Guyer ('03) has shown that there is considerable amount of degeneration in the testes of many hybrid pigeons; abnormal mitoses and misshapen spermatozoa being of frequent occurrence. Other observers have stated that the gonads in hybrids are more or less defective; but none of them have made a histological investigation in order to asertain what structural changes have been produced. Guyer's observations strongly suggest that results of value may be obtained by a study of the gonads in other hybrids. Material is being collected for an investigation of the gonads in hybrid rats, in the hope that it will at least give some clue to the cause for the increased sterility in succeeding generations of hybrids, even if it affords no evidence that will enable one to offer a satisfactory explanation for the altered sex ratio in hybrid forms.

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THE RHYTHMICAL MOVEMENTS OF LITORINA LITOREA SYNCHRONOUS WITH OCEAN TIDES.[1]

J. D. HASEMAN.

INTRODUCTION.

Through the kindness of Dr. Sumner, the writer was given an opportunity to work in the laboratory of the Bureau of Fisheries at Woods Hole, Mass., during the summer of 1907. He is indebted to Dr. Sumner for many valuable suggestions.

The purpose of the present paper is to show that the movements of *Litorina litorea*, which are synchronous with ocean tides, are not due, directly, to either geotropism or phototaxis but to the action of the film of water on the more or less exposed snails. In arriving at this conclusion many experiments were performed not only in the laboratory but also under natural conditions. In addition, the exact habitats of three species of *Litorina* were studied in detail. Such observations are necessary when the natural oscillations of *Litorina*, which correspond to the rise and the fall of the tides, are to be considered.

Lastly the writer will attempt to show that *Litorina litorea* does not retain a rhythm, which is synchronous with the tides, either in quiet aquaria or in nature when the effects of films of water have been removed by keeping the snails permanently submerged.

I. THE HABITAT OF *Litorina*.

(*a*) Individuals of *Litorina rudis* are as a rule found on rocks which lie between the tidal marks, but occasionally an individual occurs on rock weeds and even on the muddy shore. This species was abundant everywhere in the region of Woods Hole, excepting in Grape and Tashmo ponds, both of which are brackish.

(*b*) Individuals of *Litorina palliata* live as a rule on rock weeds which grow between the tidal marks. This species was not encountered at Nobska Point or in Grape, Lagoon and Tashmo

[1] The final preparation of this paper has been delayed on account of the writer's long trip in South America for the Carnegie Museum. Only the more important results are stated and many of the details have been omitted.

ponds. It is always more abundant along protected coasts and hence its absence from Nobska Point, which is exposed to the open sea, was to be expected.

(*c*) Individuals of *Litorina litorea* (said to have been imported to the American coast from Europe) usually live on rocky surfaces which lie between the high-tide mark and one foot below the low-tide mark. The species was not found in Tashmo Pond but a few young individuals were seen in Grape Pond living on transplanted oysters. This observation, taken in connection with others described below, indicates that the absence of *Litorina* from these brackish ponds was not due, directly, to the lower specific gravity that exists there.

In order to explain the restricted distribution of *Litorina* the following observations and experiments were made:

A. *Food.*—*Litorina palliata* is nearly always found on two common species of rock weeds, and its supply of food is doubtless associated with these plants, while *Litorina rudis* and *litorea* eat small green algæ which grow more abundantly on the rocks which are situated between the tidal marks.

When individuals of *Litorina litorea* were placed in shallow aquaria, which contained rocks from the sea shore, from Lagoon Pond or from the street and contained also pieces of glass and fish they came to nest for the most part on the rocks taken from normal sea water. The snails, which were taken from the entrance to Lagoon Pond with their accompanying rocks, also settled on the sea rocks.

B. *Salinity.*—When individuals of *Litorina litorea* were placed in a mixture of equal parts of fresh and sea water, they were able to crawl about; but when they were placed into a mixture of two parts fresh and one part sea water, all died within eight days. When they were placed in sea water, to which as much as fourteen grams of sun evaporated sea salt had been added to each 800 c.c. of sea water, all died within eight days. The specific gravity of the various test solutions indicated that *Litorina* could live in water which has a lower specific gravity than was observed in Grape and Tashmo ponds.

C. *Temperature.*—The variation in the temperature along the coast did not appear to affect the distribution of *Litorina*. Snails

were subjected to much greater changes of temperature than occur along the coast and no observable effects were detected.

D. *Pressure.*—Several individuals of *Litorina litorea* were submerged in cages, which contained sea shore rocks, to a depth of 8, 18 and 30 feet of water. Two weeks later the snails appeared to be perfectly normal.

E. *Aeration.*—*Litorina litorea* is very sensitive to slight changes in aëration and consequently it is very difficult to arrange the condition in an aquarium so that they behave normally.

F. No direct effects of light on the distribution of *Litorina* could be detected either by experiment or direct observations made in nature.

G. *Waves.*—When individuals of *Litorina litorea* are violently splashed by waves, they become quiescent.

H. *Character of the Surface.*—Individuals of *Litorina litorea* are rarely found on either sand or mud, due in part to the absence of food in such places and in part to the difficulty encountered in crawling over such surfaces. This is especially true when the waves constantly change the position of the same and hence tumble the snails about at random.

I. *Moisture.*— *Litorina litorea* does not crawl on dry surfaces.

II. Factors which Determine the Movements of *Litorina*.

It appears evident from the preceding data that the character of the surface, moisture and food are the chief factors which determine the litoral distribution of these snails. But as I hope to demonstrate in the following pages, these three factors produce random movements of the snails and should not be confounded with the factors which directly produce rhythmical movements corresponding to the rise and fall of the tides.

The following experiments and observations will, I think, determine what the "directive force" of rhythmical movements is.[1]

1. The snails which are located on flat horizontal surfaces between the tidal marks do not show rhythmical movements which correspond to those of the tide. The snails which are located or placed below the low-tide mark on either a vertical or a horizontal surface do not show rhythmical movements.

[1] The majority of the experiments are easily performed along the seashore by marking the snails and the stones.

But the snails which are located on any more or less vertical surface between the tidal marks do exhibit rhythmical movements which correspond to those of the tides.

2. When a stone, which has snails crawling on a flat surface below the low-tide mark, is raised and lowered in the sea, the snails do not show rhythmical movements which correspond with those of the stone, *i. e.*, their movements were not directive. The same results are obtained when, with the flat surface horizontal, the stone is raised out of and lowered into the sea. But when, with the surface vertical, the stone is raised out of and lowered into the sea, the snails at once showed rhythmical movements which correspond to those of the stone. These same snails were known (from observations made on snails placed between the tidal marks and below the low-tide mark) to have shown in some cases and not to have shown in other cases rhythmical movements during several days previous to the experiments. Therefore any alleged retained rhythm has nothing to do with the above results.

Even more interesting is the fact that when, with a vertical surface, a stone, upon which snails were crawling at random, was raised out of the sea, the snails always followed the vanishing film of water even when the vertical surface was rotated through an angle of 180°. In this case the rotation of the vertical surface would reverse the direction of motion of the film of water and the snails would at once turn around and follow it. But if most of the water was previously removed from the surface of the stone, in order that the film might entirely disappear before the snails (which were crawling downward in the direction of the vanishing film) had reached the lower surface, and if, as the film was drying up, the vertical surface was rotated through an angle of 180°, the snails continued to crawl for some time in the direction in which they had started. In other words, the snails crawled upward instead of downward. They continued to crawl thus until the rough surface, food and moisture either deflected or stopped their movements. In the above experiment, the mere turning of the moist but filmless surface through an angle of 180° does not seem adequate to reverse at once the reaction to gravity and light, if either of these have a direct influence on the rhythmical movements of *Litorina*.

3. When the eyes of *Litorina litorea* are destroyed, they still show rhythmical movements, on vertical surfaces between the tidal marks. Individuals of *Litorina litorea* also oscillate with the tides during dark nights.

4. During the months of July and August, the writer could not detect any relative change in the position of snails on large boulders. If phototaxis is an important factor, a marked change would be expected because the daily lagging of the tides as well as the diurnal and monthly changes of the relative solar position of the earth, constantly change the relative angle of the rays of light.

5. When it rains on exposed snails, they become quiescent just as they do when splashed by the water. Therefore during stormy as compared with fair days, a considerable difference in the amount of oscillations of *Litorina litorea* was noted.

6. Submerged snails could be only slightly or not at all directed by currents of water. The currents were produced artificially and also by moving stones with snails through the water. Hence the behavior of *Litorina* on vertical surface between the tidal marks is not of a rheotropic nature.

7. When individuals are left high and dry on vertical surfaces during low tide, they come to rest "directed upward," *i. e.*, with their head end toward the sky. This is true for all sides of the stones and is obviously due to the shape of the aperture of the shells which makes it far easier for exposed individuals to cling thus to vertical surfaces.

8. Individuals of *Litorina litorea* are on an average found slightly higher on the north side of large boulders than on the south side. This appears to be due to greater moisture and a higher growth of both algæ and barnacles over which snails crawl with difficulty.

9. Some bottles partly filled with water and air plus hydrogen and others partly filled with carbon dioxid were used to test the effect of crawling out of the water into a gaseous medium and vice versa. No differences were detected from that of crawling out of water into the atmosphere unless so much hydrogen and carbon dioxid were used that the snails were asphyxiated.

10. Thin films of olive oil and kerosene were placed on water

in aquaria to test the effect of surface tension. Under these conditions the snails had considerable difficulty in breaking the surface film and always hesitated at the surface pushing themselves to the right and to the left until their bodies were elevated sufficiently to break the surface tension. Their behavior under the above condition showed that the hesitation on entering and leaving the surface was due to the surface film and not to phototaxis, hydrotaxis or chemotaxis.

11. When individuals of *Litorina litorea*, *rudis* and *palliata* were placed in a small round aquarium equal areas of which were painted brown, yellow and dark olive, they as a rule came to rest on the dark olive sector, rarely stopped on the brown sector and still more rarely on the yellow sector. When the same snails were placed in a similar unpainted aquarium before a window, about one half of them came to rest on the lighter side and half on the darker side. The position of the aquaria were interchanged and the same results were obtained. Various shading experiments were tried and neither positive or negative phototaxis could be detected. In nature one sees snails crawling at random from lighter areas into shaded areas and vice versa.

The writer was unable to detect why the snails stopped on the dark olive sector, but inasmuch as such conditions are not met on vertical surfaces of stones between the tidal mark, the results appear to have nothing to do with the rhythmical movements of *Litorina*.

12. Many snails were placed in quiet aquaria and aquaria in which running water was kept at a constant level and they never exhibited any signs of oscillations which corresponded to those of the tides. In these experiments, snails which were known to have been previously oscillating with the tides were used. I also placed snails, which had been oscillating with the tides, on vertical surfaces below the low tide mark and an average of many counts did not show rhythmical movements which corresponded to those of the tides.[1] Only when the snails are touched by the surface film of water are directive movements called forth.

[1] Morse has recently obtained a similar result.

Discussion.

Mitsukuri ('01) found that the roughness of the surface scatters the snails and that they never crawl on dry surfaces. He also stated that *Litorina exigua* hesitated on entering the water and concluded that their oscillations with the tides were due to phototaxis. In this connection the writer found that the snails hesitated as much on leaving the water as they did on entering it. This fact, taken in connection with several of my experiments and especially those on surface tension, show that the observed hesitation was due to the effect of the surface film of water and not to phototaxis.

Bohn ('05) also concludes that phototaxis is the important factor which determines the oscillatory movements of *Litorina*. He states that *Litorina rudis*, *obtusata* and *litorea* have for all their lives been desiccated again and again, and when placed in quiet aquaria, all three species retained a period of rhythm synchronous with the tides and lasting from thirteen hours to fourteen days. My observations show that *Litorina litorea* does not have such an established rhythm.

The behavior of *Litorina* in experiment 2 is sufficient to show that the "directive force" in their rhythmical movements synchronous with the tides is the film of water and not phototaxis. Also the fact, that only snails on vertical surfaces between the tidal marks have oscillatory movements, shows that the directive force is not phototaxis because many snails on flat horizontal surfaces could crawl to the edge of the surface and descend to the base of the stone. Especially the observations made during dark nights as well as many other experiments already cited indicate that Bohn's view is untenable.

Conclusion.

In conclusion, then, it appears that submerged individuals of *Litorina litorea* crawl about on large stones at random, perhaps in search of food. They never crawl on dry surfaces and consequently are not found above the high-tide mark. When the tide rises, the environment is temporarily enlarged and consequently many submerged snails on more or less vertical surfaces by mere chance will crawl up higher.

The individuals which were previously left high and dry are already directed upward and hence follow the rising tide. Before maximum high tide is reached, the unevenness of the surface along with the presence and absence of food scatter the snails at random because the rapidly rising tide soon submerges them and then there is no "specific directive force."

When the tide begins to fall some of the snails are already crawling downward and those that are not will be directed thus by the surface film. During a falling tide, some snails are crawling down beneath the surface, some with the surface, and some above the surface. As the tide falls lower and lower, many snails lag behind more and more until they are finally left on filmless surfaces under which conditions there is no specific directive force and such snails are left exposed. This lagging appears to be due to feeding, rough surfaces, rough sea, rapid fall of the tide and the more rapid desiccation on certain days. As a result of all these factors the amount of oscillation varies from day to day.

The snails on either flat horizontal surfaces between the tidal marks or on any kind of a surface below the low-tide mark have no "specific directive force" and consequently do not exhibit oscillatory movements synchronous with the ocean tides.

Summary.

1. *Litorina rudis*, *palliata* and *litorea* are found in definite zones.

2. Individuals of *Litorina litorea*, located on vertical surfaces between the tidal marks, exhibit oscillatory movements which correspond to those of the tides but they do not exhibit such movements when they are located either on flat horizontal surfaces between the tidal marks or on any kind of a surface below the low-tide mark.

3. The primary directive force for rhythmical movements is the surface film of water. The secondary directive forces are the quiescent position of desiccated individuals, character of the surfaces, moisture and food.

4. *Litorina litorea* has no established rhythm in the absence of tidal changes.

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THE LETHAL EFFECT OF PURE DISTILLED WATER ON THE VINEGAR EEL (ANGUILLULA ACETI).[1]

JAMES FRANCIS ABBOTT AND ETHEL LEIGH RICHARDS.

The question of the toxicity of distilled water for aquatic organisms appears to be still an open one. An excellent summary of the literature of the subject has been given by Bullot.[2] Ringer first noted that distilled water is toxic for a variety of organisms, and attributed this toxicity to (1) an abstraction from the organism of salts which are necessary for its life, or (2) the penetration of water into the cells through osmosis, or (3) the imbibition of water by the "intercellular substance." About the same time a contrary opinion was advanced by Nägeli[3] who claimed that it is not the purity of the water but the presence of the slightest trace of copper (even so small a quantity as 1/77,000,000) that gives water its toxic qualities, whereas if water of this sort is redistilled in glass it loses its toxicity. Shortly after this, Locke questioned Ringer's conclusions and decided that the latter's results too were due to the presence of copper rather than the toxicity of the water and in 1895[4] confirmed his belief by experiments with the tadpole and *Tubifex*. Ringer[5] then retested his experiments and partially recalled his former conclusions, agreeing with Locke that "pure water (*i. e.*, that distilled in glass) is completely harmless for the animals in question. This was confirmed by Jennings for *Paramecium*, Miss A. Moore for trout and tadpole and F. R. Lillie for *Planaria*. On the other hand Lyon[6] investigated the action of distilled water on developing *Arbacia* larvæ and found that artificial sea water made up of tap water or ordinary distilled water, whether vaporized in copper or glass, is very toxic for these larvæ although tap water which has

[1] From the Zoölogical Laboratory, Washington University, St. Louis, Mo.

[2] Bullot, *Univ. of Calif. Pub., Physiol.*, I., 1904, 199.

[3] Nägeli, *Denksch. d. Schweiz. Naturforsch. Gesells.*, Bd. 33, 1893.

[4] Locke, *Jour. Phys.*, 18, 1895, 319.

[5] Ringer, *Jour. Phys.*, 22, 1897.

[6] Lyon, BIOL. BULL., 6, 1904, 198.

been boiled long enough to concentrate it one third is much less toxic than ordinary distilled water. For this and other reasons he concluded that the chief toxic agent in such waters is the ammonia which they hold in solution. In fact he found that the larvæ often developed better in ammonia-free artificial sea water than in normal sea water, a result that may be due, as he suggests, to the presence of ammonia in natural sea water.

About the same time Bullot[1] published a thorough investigation of the toxicity of distilled water for the fresh water *Gammarus* and found that the water distilled over glass with all the precaution employed in a physical chemistry laboratory was toxic for this form although to a less extent than water distilled over copper. He found, however, that the presence of NaCl in such a dilution as is expressed by a concentration of 0.00008*N* enables the *Gammarus* to live indefinitely in such a medium. Loeb[2] suggests that in such a case, "The presence of a trace of NaCl in the distilled water possibly preserves the membrane better or maintains better the secretory activity of the cells, so that the animal can be freed from the excess of water which diffuses into it."

The group of Nematodes is noted for the extraordinary resistance which the cuticle offers to external media. The common vinegar or paste eel, *Anguillula aceti*, is well known to occur normally in weak vinegar, although acetic acid is to most organisms a rapidly acting poison. *Anguillula aceti* has been observed in our laboratory to live more than 24 hours in Tellyesnicky's fixing fluid and three or four hours in Gilson's fluid. The cuticle of this worm might therefore be expected to be quite unaffected by such ions as ordinary distilled water may contain. It is of interest to note in this connection that Devaine[3] in his biological investigation of the vinegar eel observed that the worms live at most but eight days in distilled water. This effect might be due to the lack of the acetic acid which ordinarily forms a part of their normal environment or to the direct effect of the water itself. It was soon found that although the worms live best in

[1] Bullot, *l. c.*

[2] Loeb, J., "Dynamics of Living Matter," p. 50, 1906.

[3] *Compt. Rend.*, T. 61, 1865, p. 259.

an environment of weak vinegar, it is the sugar rather than the acetic acid which appears to be the essential element of the medium.

With the hope of analysing the relations of this organism to its environment, a number of lines of investigation have been taken up in connection with the reactions of the nematodes to various media and to different food substances. The present paper deals only with the effect produced on the worms by distilled water. The worms used in these experiments were found in rather stale weak vinegar of an acidity of 8/10 *N*. No difficulty was experienced in breeding them abundantly in the laboratory both in this medium and in cider. Two kinds of distilled water were employed. One of these was such as is used in the ordinary work of the laboratory. This was distilled in an automatic copper still and will be designated "A." The second water, which will be designated "B," was obtained by distilling the first kind over potassium dichromate and sulphuric acid, condensing in block tin out of contact with the air and redistilling over barium hydrate. The first six tenths of this distillate was rejected and the remainder gave an extremely pure sample, CO_2-free and showing no ammonia reaction (Nesler test) even after the lapse of twelve hours. This water when tested in a conductivity apparatus of the department of physical chemistry gave no measurable conductivity with a resistance of 20,000 ohms and may be considered to be practically free from electrolytes. It was kept in well steamed, hard glass bottles. In each experiment every precaution was taken to remove all traces of the medium in which the worms were living. The worms were washed 6 to 8 times with distilled water in a centrifuge, and in the cases where the distilled water "B" was used, two or three times more in this. They were then allowed to remain in the "B" water for about 24 hours to insure a thorough rinsing. Finally they were again washed in pure water previous to their insertion in the new medium. The bottles and test tubes used to contain the worms in the first two sets of experiments were of ordinary soft glass and in the latter ones, *Schott and Genossen*, Jena resistance glass was employed. These containers were thoroughly soaked in chromic acid, and previous to use were repeatedly

rinsed in distilled water. They were then steamed for a greater or less length of time under pressure of 150 pounds. An attempt was made to put as nearly as possible the same number of worms in each culture tube but owing to their minute size it was of course impossible to do more than approximate the number.

Contrary to expectations the worms lived much longer in the ordinary laboratory water "A," presumably full of copper and ammonia than in that distilled over potassium dichromate and free from CO_2, NH_3, copper and other ions. In "A" and soft glass tubes they lived 31 days. In "B" water and soft tubes they lived sixteen days and in "B" water and Jena insoluble tubes they lived but six days. These results would seem to indicate that the presence of the electrolytes in ordinary distilled water and of the ions dissolved from the glass prolonged the life of the worms. Because of the fact that the purer the water the greater its solvent power on glass, it is still to be determined whether this effect is due to the substances dissolved from the glass or to the copper and other ions in the distilled water itself. In the series with "B" water and Jena glass, in which the worms lived but six days, there were no impurities in the water and practically no solvents from the glass. So we are forced to conclude that the toxic character of the water itself was the cause of the death of the worms. This is borne out by observations on the behavior of the worms under such conditions. The outer integument of the nematode in contrast to its normal hardness and resistance, appeared to become very viscous after a sojourn in pure water. When any obstacle was encountered in swimming, —the side of the tube or the surface of the water, or other worms, the organisms stuck fast. This alteration of the natural condition of the cuticle was so marked that after a time the worms bunched together in masses, unable to free themselves or else coming in contact with the surface of the water, they hung suspended. This effect would seem to bear out Loeb's suggestion quoted above. That there is a marked taking up of water on the part of the organism seems quite evident. The body becomes swollen and the worms lose their elasticity, becoming more or less rigid through turgor and swimming with the body almost in

a straight line without the characteristic twitching of the ends. The worms grow more and more impotent until at last instead of swimming directly towards the surface as is usually the case, they swim in a haphazard manner and in spite of instinctive efforts to reach the top of the water are unable to advance more than an inch or two, falling back towards the bottom with every effort. This may be due to decreased vitality but may also be due to a greater weight on account of the imbibition of water. Repetitions of these experiments have confirmed the results in every instance. Experiments have been undertaken to determine what ions control or effect the permeability of the cuticle to the water.

Summary.

1. *Anguillula aceti* succumbs in six days to very pure water free from electrolytes whereas in ordinary distilled water it will live for much longer periods.

2. The toxic qualities of the pure water appear to reside in its solvent effect on the normally resistant cuticle of the worm which is rendered much more permeable to water.

3. Death is accompanied by physical manifestations suggestive of great imbibition of water by the tissues.

4. The presence of electrolytes in the medium, derived either from solution of the glass culture tube or carried by "impure" samples of distilled water, prolongs the life of the organisms in question, apparently by preserving the character of the membrane so that the tissues will not imbibe water.